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SPECIFICATIONS No. 3750

THE CARE AND OPERATION OF STORAGE BATTERIES

AMERICAN TELEPHONE AND TELEGRAPH CO.

ENGINEERING DEPARTMENT

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Replacing Bulletin No. 17 "Storage Batteries"

THE CARE AND OPERATION
OF
STORAGE BATTERIES

AMERICAN TELEPHONE AND TELEGRAPH CO.
ENGINEERING DEPARTMENT

APRIL, 1915

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APPROVED:

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SUMMARY OF IMPORTANT POINTS

SAMPLE REPORT FORMS

STORAGE BATTERIES.

PURPOSE OF SPECIFICATIONS. These specifications supersede Bulletin No. 17 issued January, 1906, on the subject of storage batteries and their purpose is to place before the Associated Telephone Companies in concise form the latest and most approved practice with regard to the operation and maintenance of storage cells of the "lead-lead" type which are now in general use in telephone central offices.

GENERAL NATURE OF THE STORAGE CELL. The active constituents of a fully charged cell of the "lead-lead" type consist of peroxide of lead on the positive plates, spongy metallic lead on the negative plates, and the electrolyte which is a solution of sulphuric acid in water. During discharge of the cell the action is to convert the active material of both sets of plates (or electrodes, as they are frequently called) into a form of lead sulphate. During discharge some of the acid in the electrolyte combines with the lead of the negative plates and the lead peroxide of the positive plates to form this lead sulphate, which action lowers the specific gravity. During charge these actions are reversed; the sulphate on the negative plates is reduced to metallic lead, the sulphate on the positive plates is oxidized again to peroxide of lead, and the specific gravity of the electrolyte rises.

It is to be noted that the sulphate of lead formed during the discharge of a cell is entirely distinct in its behavior from the hard, dense whitish form which makes its appearance when a cell is carelessly managed and to which reference is hereinafter made.

ELECTROLYTE.

ACID. The electrolyte is dilute sulphuric acid and is prepared by diluting a suitable grade of sulphuric acid with pure water. Water should never be poured into acid; always pour the acid into the water. It is important that the acid used should be essentially free from impurities. Some impurities, such as platinum, iron, copper, and many other metals, tend to cause self-discharge through local action and lower the efficiency and capacity of the battery. Other impurities, such as hydrochloric, nitric, and other acids, tend to attack and to corrode the plates. It is therefore recommended that all acid or prepared electrolyte be purchased from the manufacturer of the battery or from the Western Electric Company. Any material obtained from other sources should be carefully tested to determine its suitability for storage battery use.

WATER. It is also essential that the water used for preparing the electroyte should be pure. Preference should be given to distilled water for this purpose, but water taken from any reliable source of supply may be used if its suitability for the purpose has been proven by careful testing.

In case of doubt as to the purity of the electrolyte or its ingredients, carefully collected samples should be submitted to the manufacturer of the battery for test and advice.

The samples should be forwarded by express (never by mail or parcel post) in clean bottles with glass or rubber stoppers, carefully packed to avoid breakage. One (1) pint of acid or electrolyte and one (1) quart of water will be required for a satisfactory analysis.

If analysis shows that the amount of impurities contained in the water exceeds the amount determined by the manufacturer of the batteries as being the maximum ordinarily allowable (see table below) distilled water should be used unless the manufacturer authorizes the use of the water in

question on account of favorable operating conditions at the particular office concerned. Local conditions will determine whether it will be more economical to purchase the distilled water or to install a water still in the central office. In many cases one still could be used to furnish water for several neighboring offices. Where distilled water is purchased the source should receive consideration, as it has been found that so-called distilled water obtained from local steam or ice plants occasionally contains more of the harmful impurities than average city water.

TABLE OF ALLOWABLE IMPURITIES IN WATER.

Substance	Max. Ordinarily Permitted		Normal for Raw Water	Remarks
	Parts per 100,000	Grains per Gal.	Parts per 100,000	
Chlorine	1.0	0.3	0.1 to 1.0 (high)	Worst impurity; attacks plates, forming up the positives.
Nitrates	1.0	Trace	Trace not noticeable	Attacks positives but is then decomposed.
Iron	0.15	0.03	0.005 to 0.1 (high)	Attacks and sulphates the positives.
Organic & volatile	10. (approx.)	6.	1 to 3 (sometimes 10)	Danger of forming harmful organic acids.
Fixed residue upon evaporation	10. (approx.)	6.	Variable	These salts tend to neutralize the acid and in some cases affect the negatives.

An excess of any one of these substances, except iron, is usually cause for rejection of the water. The figure for iron, while not up to the harmful limit, is abnormally high

for most waters, and therefore, cause for suspicion, and indicates some source of contamination, such as rusty pipes, which at times might render the water dangerous.

CARE OF ELECTROLYTE. It is also necessary to take extreme care that no impurities enter the electrolyte after it has been added to the cell. Trouble is most likely to occur from the introduction of metallic substances into a cell, such as tools, bits of wire, etc. Should it be known that any metallic substance has fallen into a cell, it should be immediately removed. If the substance is not immediately removed, or if there is any doubt as to whether the electrolyte has been contaminated the solution should immediately be changed. Before putting in the new electrolyte the cell should be thoroughly flushed with water. The change should be made when the battery is discharged and just before charging. Do not allow the plates to dry. (See page 25).

In this connection it should be remembered that should there be iron work above the cells injurious iron salts may be formed by the action of the acid fumes or by ordinary rusting unless the iron is properly protected by a reliable paint or varnish (see page 31), and that these salts may fall into the cells.

SPECIFIC GRAVITY. The electrolyte furnished for use in storage cells should have a specific gravity of 1.210; a leeway of five points (.005 Sp. Gr.) above or below this value is permissible. It is prepared by mixing one (1) part by volume of acid (of 1.835 specific gravity=66° Beaumé) with four (4) parts by volume of water. The acid must be poured into the water; **never pour water into the acid.** The acid should be poured into the water slowly and carefully, not only to prevent excessive heating, but more particularly splashing. on account of the painful and dangerous character of acid burns. The specific gravity of the solution should be determined only when it has completely cooled. The speci-

fic gravity of the solution should be finally adjusted by the addition of small amounts of acid or of water until the prescribed specific gravity has been secured. The vessel used for mixing must be a lead-lined tank, one of glazed earthenware, or one of wood which has not been used for any other purpose, such as a new wash-tub. Wooden vessels, however, must not be used for storing electrolyte.

Corrections for Temperature Variations. Allowance must be made for variations in the temperature of the electrolyte from the normal value of 70° F., in order that all specific gravity readings may be upon the same basis for purposes of comparison.

To correct a given hydrometer reading for variations from the normal temperature of 70° F., for each three (3) degrees of temperature variation, one point, (.001 Sp. Gr.), should be subtracted if the temperature is below 70° F. or should be added if the temperature is above 70° F. For example, a hydrometer reading of 1.212 with the temperature at 64° F. would be 1.210 corrected, while a reading of 1.212 at 76° F. would be 1.214 corrected.

Wherever specific gravity is referred to in these specifications **corrected values** are meant unless otherwise stated.

ADDITION OF ACID.

On account of loss of acid from the electrolyte through absorption by the sediment and through spraying at the end of charge there is a gradual lowering of the specific gravity of the electrolyte, the rapidity of the change depending on the work the battery does and the care with which it is operated. When on account of the above causes the specific gravity of the electrolyte at the end of an overcharge and at normal temperature has fallen to 1.180 it should be brought up to standard by the addition of new electrolyte of 1.210 specific gravity instead of water when replacing evaporation loss. Under special conditions where properly qualified supervision is available, acid of 1.400 specific gravity may be used to bring up the gravity of the

electrolyte. Improper use of 1.400 gravity acid may injure the plates. Adjustment of the specific gravity should not be necessary oftener than about once every two (2) or three (3) years.

NEVER UNDER ANY CIRCUMSTANCES RAISE THE SPECIFIC GRAVITY OF THE ELECTROLYTE IN A CELL WITHOUT FIRST DETERMINING IF THE LOW GRAVITY IS DUE TO PARTIAL CHARGE, SHORT CIRCUITS, OR GRAVITY READINGS UNCORRECTED FOR TEMPERATURE.

ADDITION OF WATER. Only pure water (see page 2) should be used to replace loss by evaporation. The electrolyte must never be allowed to get below the top of the plates nor must the cells be filled too full. The water should be added at the top of the cell with sufficient frequency to keep the electrolyte from 1/2 inch to 3/4 inch above the top of the plates. The water should be added carefully and splashing or slopping avoided. It is recommended that the water be added immediately before or after starting a charge, preferably an overcharge, after the cell readings have been taken. The ensuing charge will then cause the water to become thoroughly mixed with the electrolyte.

INITIAL CHARGE.

GENERAL. New battery plates, as received from the manufacturer, are generally in a more or less sulphated condition, particularly the negative plates. When these plates are installed in the cells and covered with electrolyte, the amount of sulphate on all the plates is increased to some extent due to absorption of acid from the electrolyte. The purpose of the initial charge is to completely convert this sulphated active material of the positive and negative plates into lead peroxide and

spongy lead respectively, thereby preparing the battery for service.

Before the electrolyte is put into the cells, the circuits connecting the battery with the charging source must be complete and of the proper polarity. The positive pole of the charging source must be connected with the positive end of the battery. The positive plates are of a brownish color, the negatives of a light gray. Sometimes new negative plates will have whitish spots. These are harmless and will generally disappear after the cells have been in service a few months. The grids of new positive plates are frequently covered with a thin scale. This is also harmless and will flake off in time. Charging in the reverse or wrong direction will seriously injure the battery.

As the life of the battery is materially influenced by the initial charge, it is of great importance that this charge be complete before allowing the battery to discharge.

Installation of Wood Separators. Cells are usually fitted with wood separators and these should be installed in accordance with the directions furnished by the manufacturer. Wood separators are shipped wet and must not be allowed to become dry. If there is any delay in setting up the battery the separators should be left in the packing cases and kept wet by being frequently sprinkled with water, at least once a week, the lid of the case being removed while sprinkling.

CHARGING.

Rate and Duration of Charge. The charge should be started as soon as practicable after the electrolyte is in all the cells, but under no circumstances should there be a delay of more than four (4) days in starting the charge. The charge should, if possible, be at the normal rate recommended by the manufacturer, and should be continued until both the specific gravity and voltage of each cell reach a ten-hour maximum, i. e. show no further rise or increase during a period of ten (10) hours and bubbles of gas are being freely given off from all the plates, both positives and negatives. The posi-

tive plates will gas some time before the negative plates begin to gas. If it is necessary to charge at a rate less than normal the 10-hour period must be proportionately increased. The temperature of the electrolyte should be watched, and if it reaches 110° F., the charging rate must be reduced or the charge temporarily stopped until the temperature lowers.

The **minimum** time required, **at normal rate,** for the initial charge is generally from thirty (30) to fifty (50) hours, the shorter time applying to types of cells in which the negative plates are shipped in a partially formed condition. If the charging rate is less than normal the time required for the charge will be correspondingly increased. If necessary, the charge can be interrupted, for instance over night, but the interruption should not be longer than ten (10) or twelve (12) hours. In case the charge is interrupted, particularly during its earlier stages, or if it is not started soon after the electrolyte is in the cells, the total charge required (in ampere hours) will be greater than if the charge is continuous and started at once. The charging current should not be allowed to exceed the normal rate by more than ten (10) per cent. and after the first twenty-five (25) hours of the charge must be kept as near the normal rate as possible.

Readings. As a guide in following the progress of the charge, readings should be taken and recorded hourly, as indicated by the accompanying "Storage Battery Initial Charge Report" form. The gassing should also be watched, and if any cells are not gassing or are not gassing as much as the surrounding cells they should be carefully examined (see page 21) and the cause of the trouble removed.

Addition of Water. Water should be added to the cells as required to keep the electrolyte at its normal level, from 1/2 inch to 3/4 inch above the top of the plates.

Specific Gravity. The specific gravity will fall rapidly after the electrolyte is added to the cells owing to the for-

mation of lead sulphate on the plates as explained on page 6, and the water from the wood separators, and will subsequently rise gradually as the charge progresses, until it again reaches its original value or thereabouts.

If the specific gravity of any cell at the completion of the initial charge, with the level of the electrolyte at the proper height above the plates, is more than five points (.005 Sp. Gr.) above or below the mean value recommended by the manufacturer, it should be adjusted to the proper figure. Due allowance should, of course, be made for temperature, and electrolyte should be added if the gravity is low while some of the electrolyte should be replaced by water if the gravity is high, keeping the surface as nearly as possible 3/4 inch above the top of the plates.

Voltage. The voltage at the end of charge, while approximately 2.55 volts per cell, is not a fixed value, and for this reason a definite voltage should not be aimed for.

OPERATION.

EXCESSIVE CHARGING MUST BE AVOIDED, AND A BATTERY MUST NOT BE UNDERCHARGED, OVERDISCHARGED, OR ALLOWED TO STAND COMPLETELY DISCHARGED.

PILOT CELL. **General.** One of the cells of the battery is to be used as a guide in the operation of the battery as a whole. For this purpose a readily accessible and well lighted cell is to be selected and known as the "pilot cell." Where all the plates in the battery are not of the same age, as when the plate equipment is increased or partial renewals made, the pilot cell should be one of those having the oldest plates. Readings are to be taken on this cell with sufficient frequency to indicate its state of charge and discharge, which will thus serve as a guide in the operation of the battery as a whole.

The pilot cell, when once selected, should not be changed, unless the cell has to undergo special treatment or repairs.

Addition of Water. The height of the electrolyte in the pilot cell should be kept at a fixed point, and above the top of the plates. This may be done automatically, or a small quantity of water may be added by hand often enough (at least once a day) to keep the height accurately at the proper point. This will prevent the sudden drop in the specific gravity of the electrolyte consequent upon the addition of a considerable quantity of water and the following increase in specific gravity as it evaporates. If not filled automatically, the fixed point should be marked in a convenient manner; for instance, in a glass-jar battery by a narrow painted line on the outside of the jar, or in tanks by an S-shaped strip of lead hung over the edge of one of the glass supporting plates.

Displacement Tanks and Blocks. In order to obtain as great a range in gravity on charge and discharge as possible, it is necessary in batteries in which the number of plates per cell is less by four (4) or more than the full tank capacity that the excess of electrolyte in the pilot cell should be displaced. A tank specially constructed for this purpose and filled with 1.210 electrolyte is used in batteries set up in tanks; if in glass jars, a wooden block, properly treated and weighted, may be used.

CHARGING.

General. It is important that **the battery should be given the proper amount of charge,** as indicated below, but **excessive charging must be avoided,** as not only will an unnecessarily rapid accumulation of sediment and excessive evaporation of the electrolyte result, but, what is more important, the life of the plates will be very much shortened.

From the standpoint of power economy, life of the battery and provision for emergency reserve, the best practice is the method which embraces what may be called a "regular charge," to be given when the battery is from one-third

(1/3) to one-half (1/2) discharged, and an "overcharge," to be given weekly if it is necessary to charge the battery daily (either six or seven days a week), or once every two weeks if the regular charge is not given so often.

Specific Gravity vs. Voltage Method. The readings of the specific gravity of the electrolyte in a pilot cell, or of the voltage of the battery can be used as a guide in following the charge. **The specific gravity method is to be preferred,** owing to its being independent of the rate of charge, and more accurate than the voltage method. The latter method is not recommended except under very special conditions. Voltage readings are to be used as a check on the gravity and also in cases where due to the character (2-plate cells) or inaccessibility of the cells, the gravity method is not practicable.

Gravity Method. It has been previously stated (see page 1) that during discharge the specific gravity of the electrolyte is lowered, owing to the removal of part of its sulphuric acid to form lead sulphate, and that, on charging, this lead sulphate is decomposed. The sulphuric acid thus set free again enters the electrolyte, which as a result is raised to a higher specific gravity. The quantity of sulphuric acid which is removed from the electrolyte is dependent on the quantity of active material which is transformed, or practically on the number of plates in the cell and the extent to which they are discharged. The change in the specific gravity of the electrolyte depends on the relation of the quantity of acid uniting with active material to the quantity of electrolyte in the cell. If the quantity of electrolyte is increased, the plates remaining the same, the fall in gravity due to a given discharge (in ampere hours) will be lessened as the same quantity of acid is taken from a larger quantity of solution. In using the gravity method for observing charge and discharge, it is therefore essential that the ratio of the volume of the electrolyte to the quantity of active material should always remain constant. This is the reason for the rules for the care of the pilot cell which provide for keeping

the level of the electrolyte at a fixed point and supplying a displacement tank when four or more plates less than the full tank capacity are installed.

Voltage Method. When, owing to the character (2-plate cells) or inaccessibility of the cells, the gravity method of operation cannot be used it is necessary to operate the battery by the voltage method. When using this method it is important that the charging rate should be kept uniform, and it is preferable that the charging should be at the normal rate, as under these conditions the best specific rules for voltage operation can be given. If the charging rate is less than normal, it is necessary to make a reduction in the required voltage for end of charge, which can be only approximately estimated. In all cases where the voltage method of operation is used it is essential that for at least two (2) hours preceding the completion of the charge the charging rate should be uniform and not less than fifty (50) per cent. of the normal rate, as satisfactory voltage operation cannot be secured except under well-defined conditions. As mentioned above, the voltage method should be used only when the gravity method is not practicable.

Charging Rate. The normal charging rate is usually the eight-hour discharge rate, i. e., a rate which will give a complete discharge of the battery in eight (8) hours. To bring a battery from a state of complete discharge to a state of complete charge will, due to the battery losses, require charging at the normal rate for a longer period than eight (8) hours.

The normal rate is assigned by the manufacturer as a desirable rate at which to charge the battery. Any charging rate which does not cause gassing is, however, permissible, even several times the normal rate, during the early part of a charge following an extended discharge. To avoid excessive wear of the plates a high rate must not be used toward the end of charge and **the normal rate must not be exceeded after the battery starts to gas.** If the battery voltage is not allowed to exceed an average of 2.30 volts

per cell at any time, when charging at rates higher than normal, gassing will be avoided. With the gravity method of operation it is not necessary to charge at a uniform rate, as the gravity indicates closely the state of charge. The gravity method of operation is recommended wherever it is possible.

Economy of Power. The charging generator attains its greatest efficiency in transforming power into electrical energy for telephone purposes when it is supplying a current at from 3/4 to full load. At certain periods of the day the office load is comparatively heavy, and if during these periods the generator is operated at or near its rated output some economy in the cost of power can be effected. This is due, first, to the fact that the generator is thereby working at a high efficiency and, secondly, to the fact that energy for the operation of the office is supplied directly from the generator, and the losses occurring when energy is transformed in the battery are avoided.

In planning for the economical operation of the power plant it is necessary to consider the rated output of the generator, the exchange load, and the proper charging rate for the battery. As the relation of the rated output of the generator to the other factors may vary considerably in different installations, the following rules are given for guidance in securing economical operation:

1. When the rated output of the generator is sufficient to carry the office load and the normal rate of the battery, charge the battery at the normal rate.

Note: Where the generator size permits, and it is desired to shorten the time of charge, the normal rate may be exceeded as previously outlined, until the battery reaches the gassing stage.

2. When the rated output of the generator is less than the office load plus the normal rate of the battery, charge at full load on the generator.

Note: Where a reserve generator is provided and is arranged for parallel operation, it may be found desirable to run both machines during the period of heaviest office load.

3. In applying the above rules it should be noted that it is economical to carry as much of the office load from the generator as can be done efficiently. This may make it advisable in some cases, particularly under rule 1, to reduce the generator output in order to prolong the time of charge. It is ordinarily not economical to operate the smaller charging sets (less than approximately 300 amperes capacity) at less than half load, or the larger sets at less than one quarter load.

Regular Charge. The allowable drop in the specific gravity of the electrolyte before starting the charge depends in any particular case upon the reserve capacity desired, and the charging, whether done daily or less frequently, should be started at such a time as will insure that this capacity is available at the time the attendant regularly leaves the office for the day.

The twenty-four hour central office drain on a battery having one day's capacity will cause the specific gravity of the electrolyte in the pilot cell to fall approximately the number of points shown in the table on page 18, and in the case of a battery having three days' capacity the drop in specific gravity during twenty-four hours will equal approximately one-third of these values.

If the voltage method only is used for observing charge and discharge, as for small 2-plate cells, no single rule can be given for determining when the charge should be started, as the voltage varies with the rate of discharge. For special directions on the voltage method see under "Voltage Limits" page 18.

The battery should be charged until:

(a) The gravity of the pilot cell has risen to a value which is five points (.005 sp. gr.) below the maximum reached on the preceding overcharge; for instance, if the

maximum reached on the preceding overcharge was 1.209, the gravity to be reached on the regular charge is 1.204.

(b) The voltage across the battery has risen to a value which is .05 to .10 volts per cell below what it was on the preceding overcharge, the charging rate being the same in both cases; for instance, if the maximum voltage per cell attained on the overcharge is 2.52, the voltage per cell to be reached on the regular charge is from 2.42 to 2.47 volts per cell (see 'Voltage at End of Charge," page 16).

(c) The cells are all gassing decidedly but not as freely as on overcharge.

Overcharge. If the battery is charged daily (six or seven days per week), then once each week, on the same day of every week, the regular charge should be prolonged until:

(a) The gravity of the pilot cell has reached a one-hour maximum, i. e., five (5) successive 15-minute readings of this cell show no further rise. If the charging rate is less than normal the length of the overcharge period should be proportionately increased. For instance, if the charging rate is half the normal, the number of successive 15-minute readings should be increased to nine (9).

(b) The voltage across the battery has reached a maximum, five (5) successive 15-minute readings showing no further rise, the charging rate being kept constant. At charging rates less than normal the number of successive 15-minute readings should be increased as under (a).

(c) The cells are all gassing freely.

If the battery is not charged daily (less than six days per week) then the overcharge should be given only once every two (2) weeks.

When giving the cells the "overcharge," arrangements should be made to give the latter portion of the charge at a uniform and, where practicable, at approximately the normal rate, whether specific gravity or voltage operation is followed. As the determination of the end of the overcharge

depends on the securing of a series of successive uniform gravity and voltage readings, it is important that, during the last hours of the overcharge, the charging rate should be approximately constant.

Voltage at End of Charge. The voltage at the end of charge is not fixed throughout the life of a battery, but will vary, due to several causes, namely, the age of the battery, the temperature and specific gravity of the electrolyte, and the charging rate. Therefore, a maximum voltage as described under "Overcharge" above, and not a definite or specific voltage must be considered when using the voltage method in determining the end of charge.

When first installed, the voltage at the end of overcharge, with the normal charging current flowing, should be approximately 2.55 volts per cell, with the temperature at 70° F., (under exceptional conditions the voltage per cell may reach 2.70), but as the age of the battery increases this voltage will gradually decrease, until in some cases, with both the charging rate and temperature normal, it will have fallen to 2.40 volts per cell, or thereabouts.

The effect of changes in temperature on the final charging voltage is that it is noticeably lowered with an increase in the temperature above normal (70° F.) and correspondingly increased with lowered temperatures, irrespective of the age of the battery.

Higher or lower rates of charging than the normal will, respectively, produce slightly higher or lower final charging voltages.

Voltage and Specified Gravity after Charge. After the completion of a charge and the cutting off of the current, the voltage per cell will fall quite rapidly to between 2.05 and 2.10 volts.

As the discharge is started the voltage will fall to approximately 2.00 volts per cell, depending on the rate.

Also, after the completion of a charge, particularly an overcharge, the specific gravity of the electrolyte will rise slightly, due to the passing off of the gas bubbles formed

during the charge; for this reason the pilot cell gravity readings must be taken before the charging current is cut off.

FLOATING. When the battery has been given its proper charge, it may often happen that the office load will remain for some time at a value which is a considerable proportion of the generator rating. If the cost of power is low, it may be profitable to run the generator to carry the office load and thus avoid the transformation losses in the battery. This can be done if the battery is "floated," i.e., if the output of the generator is regulated approximately equal to or slightly less than the office drain. Temporary fluctuations in the office drain will result in slight discharge of the battery if they are in excess of the average, or in slight charge if they are below the average.

DISCHARGING. **Specific Gravity Variation.** The fall in gravity of the electrolyte is very closely in direct proportion to the ampere hours taken out and for this reason is the best indication of the amount of discharge.

The total gravity drop for a complete discharge varies for different types and sizes of cells depending on the relative bulk of the plates and electrolyte. As the small size cells of any type have a relatively large bulk of electrolyte they therefore have a smaller range than the large size cells of the same type. The following table gives the approximate range for a complete discharge for cells of different types equipped with the full number of plates. If the cells have less than the full number of plates, the range in gravity is proportionately reduced, except in the case of the pilot cell, which should be equipped with a device for displacing the excess electrolyte (see "Displacement Tanks and Blocks" page 10). For telephone service in general, however, charging should be started when the specific gravity on discharge has fallen approximately from one-third (1/3) to one-half (1/2) the range given in the table (see "Regular Charge"

page 14). In emergency cases, however, all the capacity that the battery will give and still maintain service may be used without regard to the specific gravity drop.

SPECIFIC GRAVITY RANGE FOR COMPLETE DISCHARGE

TYPE	E						F—STYLE A JARS				F—LEAD LINED TANKS					
No. of Plates	5	7	9	11	13	15	9	11	13	15	9	11	13-15	17-19	21-23	25-27
Sp. Gr. Range (Approx.)	22	30	33	37	40	42	32	36	40	42	22	24	26	29	31	32

TYPE	G												
No. of Plates	9	11	13	15	17	19	21-23	25-27	29-33	35-39	41-49	51-59	61-75
Sp. Gr. Range (Approx.)	26	29	31	33	35	37	38	40	42	43	44	45	46

Voltage Limits. The voltage of a battery is affected by the rate of charging or discharging and for this reason cannot be used to indicate the state of the charge or discharge without taking the rate into consideration. The following table gives the average cell voltage at different discharging rates to which it is considered safe to allow a cell to drop and yet insure a reserve in case of emergency:

Discharging Rate	Voltage per Cell
Normal	1.90
3/4 "	1.92
1/2 "	1.94
1/4 "	1.96
1/10 "	1.97

For allowable voltage limits when making a capacity test see page 38.

As stated above, the fall in gravity method of determining the amount of discharge is the most reliable and is to be preferred under ordinary conditions.

READINGS. **General.** As a guide in following the operation and general condition of the battery, and also for a record of the same, **it is important that readings be regularly taken and recorded.** The following are suggested:

Daily Readings. The specific gravity and temperature of the pilot cell, the voltage across the battery and the battery current should be read and recorded just before the beginning and end of every charge. Readings of the pilot cell specific gravity should also be taken hourly during the charge but need not be recorded.

On days when the battery is not charged the gravity and temperature of the pilot cell should be read and recorded at the usual time of starting the charge.

It is desirable, when there is a regular attendant stationed in the office, to take a reading of the specific gravity of each cell at least once each day. These readings need not be corrected for temperature and need not be recorded. If the gravity readings indicate anything unusual in connection with the battery, individual cell voltage readings should also be taken.

Weekly Readings. Before starting the overcharge, if the battery is overcharged weekly, and also on the corresponding day of the off week if not overcharged weekly, a gravity reading of each cell in the battery should be taken and recorded. The above cell readings should be carefully examined and any cell showing a falling off in specific gravity relative to the surrounding cells should be noted, **and as soon as possible inspected and the cause removed.** (See "Inspection," page 20). During the overcharge, and beginning when the specific gravity reaches a value from two (2) to five (5) points below the maximum reached on the preceding overcharge, readings of the pilot cell specific gravity,

and the battery voltage and current, should be taken and recorded at 15-minute intervals, until five (5) successive readings of the specific gravity and voltage show no further rise. Within 15 minutes after stopping the overcharge a gravity reading of each cell should be taken and recorded.

Exchange Load Readings. It is suggested that at intervals of about six (6) months, readings of the exchange load be taken over a period of twenty-four (24) hours. These readings should be taken at 15-minute intervals during the day and, when practicable, at hourly intervals during the night. Care should be taken to select a day representative of the average conditions of service (preferably a peg-count day), rather than one when extraordinary conditions prevail, as on holidays and Sundays. These readings will assist in checking up the operation of the battery.

CARE OF THE BATTERY.

INSPECTION. **General. A careful inspection of each cell should be regularly made.** The most suitable time for an inspection is before the overcharge, so that if any trouble is discovered it can be removed in time for the cell to get the benefit of the overcharge.

In making the inspection an ordinary incandescent light on an extension cord can be used and a careful examination should be made between the hanging lugs to see that the separator dowels are in place and the lugs are not touching; also anything unusual in the color or appearance of the plates should be carefully noted.

Some moss (spongy lead) may form on the top of the negative plates, and should it accumulate to a considerable amount it should be removed before it bridges across to the positive plates and causes a short circuit. A heavy accumulation of moss usually indicates excessive charging.

On the top of the positive plates a thin coating of fine powder will form which can be easily brushed off. With

proper charging this powder will be of a dark yellowish color and the surface of the grid beneath a dark chocolate color; with excessive charging the powder will also be of a dark chocolate color.

Special attention should be given to cells that read low at the time the cell readings are taken. Look for the cause of the trouble and remove it as soon as possible, and not later than the beginning of the overcharge. Short-circuits should be removed with a thin strip of glass, hard rubber or well-seasoned wood; **never use metal.**

Near the end of the overcharge all cells should be examined to see that they are gassing freely. The height of the electrolyte affects the appearance of gassing; if the electrolyte is down to the top of the plates and the cell otherwise normal, the amount of gas given off will apparently be much less than when the electrolyte properly covers the plates.

All cell connections should be inspected to see that they are clean and tight.

In addition to the above, the accumulation of sediment in the bottom of the cells should from time to time be noted; it must not be allowed to reach the plates (see "Sediment," page 31).

CELLS IN TROUBLE.

Indications of Trouble. The following are the chief indications of trouble in a cell:

FALLING OFF IN SPECIFIC GRAVITY OR VOLTAGE relative to the surrounding cells.

LACK OR DEFICIENCY OF GASSING on overcharge as compared with surrounding cells.

COLOR OF POSITIVE PLATES markedly lighter than those in surrounding cells.

In case any of the above symptoms are found in a cell, examine carefully for the cause and REMOVE IT AT ONCE.

Treatment. The above symptoms in a cell indicate that it is "low" i.e., has fallen below the rest in its state of charge. If the cause is discovered and removed immediately, it will usually be restored to normal condition by the following overcharge. If then only partially restored, it must be carefully watched during the ensuing week. If the next overcharge does not completely restore it, or if the original deficiency was excessive, it may be necessary to give it a special charge.

Special Charging. The first and simpler method of treating a low cell is to overcharge the battery, but care should be taken not to carry this to excess.

The second method is by giving an individual charge while the battery is on discharge. This charge can usually be given over special leads from the generator side of the regular charging switch. Care should be taken not to close this switch while giving the individual charge. In the case of large generators having multiple plate field rheostats, it may be necessary to disconnect one or more of the plates in order to sufficiently reduce the generator voltage.

Before putting a cell that has been in trouble into service again, care should be taken that the cell has been fully charged, this being determined by continuing the charge at normal rate until at least a five-hour gravity and voltage maximum is reached, six (6) or more successive hourly readings of each showing no further rise and gas is being freely given off from all the plates. If the charging rate is less than normal the length of time at maximum must be proportionately increased.

Replacing Bolted Connections. When bolted connections have been disconnected they should be replaced with care to avoid heating and increase in resistance of the battery circuit. The following method is recommended: Wipe the bolts and straps clean, scraping the abutting surfaces of the straps to a bright finish, then join in the usual manner after dipping the brass bolt in vaseline. When the con-

nections have been tightened, scrape a small V-shaped groove approximately 1/16 inch to 1/8 inch deep across the top of the lugs where they meet by means of a sharp file or other square-edged tool. Rub a piece of tallow in the groove and melt the two surfaces together with a very hot soldering iron. Several hours after bolting the connections they should be gone over and tightened and after the succeeding charge is completed they should be tightened a third time. This is necessary to take up the "slack" due to the deformation of the lead under pressure.

BATTERY IN TROUBLE.

Decrease in Capacity. In some cases a battery as a whole, although receiving its usual amount of charging, may show a decrease in capacity before this can be accounted for by the natural wear on the plates. If after prolonging three (3) or four (4) of the usual overcharges to nine (9) 15-minute maximum readings (two-hour maximum), and with normal routine restored, the capacity again shows a decrease, it is probable that the fault is with the negative plates, in which case a reduction of the specific gravity of the electrolyte will generally restore them to normal condition.

The most suitable value to which to reduce the gravity is approximately 1.170 at end of overcharge. This reduction is accomplished by drawing off some of the electrolyte and replacing with water. After reducing, charge to a ten-hour gravity maximum; if the specific gravity rises during the charge to a value greater than 1.170 again reduce to this value. In such cases it is preferable to continue operating the battery at this low gravity for the remaining life of the plates. If, however, it is desired to restore the gravity to its normal value in order that the operating routine may be the same at all offices, this should be done gradually by replacing evaporation with 1.210 electrolyte until the normal value is reached. In any case, however, the battery should be operated with the low gravity electrolyte for at least two months.

Sulphated Plates. During the discharge of a battery there is being formed sulphate of lead, as explained under "General Nature Of The Storage Cell" on page 1. If, however, charging is neglected, the sulphate reaches a condition which tends to fill the pores of the plates and make the active material dense and hard. It is this condition which is ordinarily referred to as "sulphated."

The cause of this condition is some form of abuse, such as: standing discharged for some length of time; habitual undercharging; neglecting evidence of trouble in individual cells; adding acid to the cell to restore the specific gravity instead of bringing the acid out of the plates by proper charging.

The lead sulphate formed in a normal discharge of a battery is in a form in which it absorbs the charge very readily. When a battery is "sulphated," as ordinarily expressed, the sulphate is then in an abnormal condition and absorbs the charge with difficulty, and the ordinary charge is insufficient.

Sometimes new negative plates have whitish spots. This is not sulphate, but hydrate. It is not dangerous and will generally disappear after the cells have been in service a few months.

Treatment of Sulphated Plates. The reduction of abnormal sulphate can be accomplished by prolonged charging, preferably at about one-half the normal rate, the charge being continued until at least a ten-hour gravity and voltage maximum is reached, eleven (11) or more successive hourly readings of each showing no further rise and gas is being freely given off from all the plates.

In extreme cases of sulphating, when a battery has been taken out of service improperly by withdrawing the electrolyte while the cells are in a discharged condition and then allowing the plates to dry without thoroughly washing them, the reduction of the sulphate can best be accomplished by prolonged charging as above but in extremely weak electrolyte, about 1.050 specific gravity. (See "Putting Battery Or Individual Cells Into Commission" page 27).

Results of Overcharging. Should a battery be repeatedly overcharged to excess an abnormal amount of active material will be formed on the positive plates which may cause them to buckle. Part of this excess material will be thrown off causing a rapid accumulation of sediment and the formation of moss on the top of the negative plates.

TREATMENT OF DRY PLATES. If for any reason the negative plates of a cell have been allowed to dry, a long time will be required for charging, the time usually being from thirty (30) to fifty (50) hours at the normal rate, or its equivalent in ampere hours at a lower rate. For this reason, drying of the negative plates in a working battery is to be avoided.

Positive plates, if dry, will require but a comparatively short charge; if they are in a fully charged state when taken out of a cell, from six (6) to eight (8) hours will be sufficient; if discharged, then somewhat longer, depending on the extent of discharge and length of time they have been exposed to the air.

In any case both the positive and negative plates of a cell must be fully charged before being allowed to discharge (see "Special Charging," page 22).

BATTERY OR INDIVIDUAL CELLS USED BUT OCCASIONALLY. If the battery is used but occasionally or is standing idle, it should be given a freshening charge every two (2) weeks; this also applies to any cells that may be temporarily out of circuit.

BATTERY TEMPORARILY OUT OF SERVICE. Under exceptional circumstances it may be necessary temporarily to take the entire battery out of service for repairs. In such a case the best procedure is to substitute a portable battery as the charging generator alone should not be used for current supply on

account of the noise developed by these machines and the unreliability of the arrangement. In substituting the portable battery for the central office battery care should be taken not to interrupt the current supply to the office.

If a portable battery is not available, the noise of the machine may be sufficiently reduced by bridging several water rheostats in multiple across the charging mains. When water rheostats are used they should be connected across the mains with the charging generator in operation. At first the plates of the rheostats should be kept far apart, but, as the electrolyte is removed from the cells to allow the repairs to be made, the plates should be moved nearer together, until when the circuit through the battery is broken the current flowing through the rheostats is the same as that originally flowing through the battery. When the battery is restored to service, the plates of the rheostats should gradually be separated until the proper current through the battery is again obtained. This method should not be used except as a last resort after all efforts to obtain a portable battery have failed. An automobile battery can often be used to advantage.

PUTTING BATTERY OR INDIVIDUAL CELLS OUT OF COMMISSION. If the use of the battery or any of its cells is to be discontinued for a period not exceeding twelve (12) months and it will not be convenient to give it a freshening charge at regular intervals (see "Battery Used But Occasionally") care should be taken that an overcharge is given just before the idle period. Water should be added to the cells during the overcharge so that the gassing will insure thorough mixing. The level of the electrolyte should be about 1/4 inch from the tops of the jars or tanks. After the overcharge is completed, remove the fuses to prevent the use of the battery during the idle period. Although not likely, the level of the electrolyte may, due to excessive evaporation during the idle period, fall below the tops of the plates. If this should occur, add water to keep them covered; if in

a place where freezing is apt to occur, stir the electrolyte after adding the water, as thoroughly mixed electrolyte will not freeze solid.

If the battery is to be entirely out of service for over twelve (12) months, then proceed as follows: After thoroughly charging and determining that there are no low cells, syphon off the electrolyte which may be used again if desired. As each cell becomes empty immediately fill it with fresh, pure water. When water is in all the cells, allow them to stand twelve (12) or fifteen (15) hours; then draw off the water and immediately remove the wood separators. The cells will then be in condition to stand indefinitely. If the old electrolyte is to be saved it should be stored in carboys thoroughly cleaned and tightly sealed to keep out impurities. The old separators should be thrown away and new ones used when the battery is again put in service.

If there is any considerable amount of sediment in the cells, advantage should be taken of the out-of-service period to clean them thoroughly before the sediment dries and becomes hard.

PUTTING BATTERY OR INDIVIDUAL CELLS INTO COMMISSION AGAIN. If the electrolyte has not been withdrawn, all that is required is to add water, if needed, to the cells and give an overcharge until the specific gravity of the electrolyte has ceased rising over a period of five (5) hours.

If the battery has been standing without electrolyte, proceed as follows: Equip cells with new separators and immediately fill them with either new electrolyte of the proper specific gravity (usually about 1.210) or, if the old electrolyte has been saved, add enough new to replace that lost in handling. When all the cells are filled the charge should be started.

This charge is similar to the initial charge of a new battery. The rate should be normal, and continue for a period of ten (10) hours after the specific gravity and the

voltage of each cell have ceased rising. From thirty (30) to fifty (50) hours at the normal rate will be the minimum time required to complete this charge as explained under "Initial Charge." If the rate is less than normal, the time required will be correspondingly increased. It is of the utmost importance that this charge be complete.

ADDITION OR RENEWAL OF PLATES.

In adding new plates to batteries, either as partial renewals or to obtain greater capacity, the following method is recommended:

1. In cases where the batteries have been installed six (6) months or less, or one (1) year if the battery has been charged less frequently than once every other day and the plates of which are consequently but slightly worn, the addition can be made by simply installing the new plates in the same cells with the old plates. The new negative plates in such cases must be furnished in a charged condition and must be so ordered in the requisition. Charged negatives are shipped wet and must be kept so until installed; if they are allowed to dry they will require a charge of from thirty (30) to fifty (50) hours as explained under "Initial Charge" page 6.

Plates of like kind but of different age should not be installed in the same cells except under the above conditions.

2. When the addition is made to a battery which has been installed longer than given in (1) the plates should be grouped so that like plates are of the same age, but old negatives and new positives, or vice versa, may be installed in the same cells.

3. Old plates that may remain after setting up the battery and are in good condition should be thoroughly washed, dried and returned to stock to be used for making additions to batteries of like age.

4. In case (2) the cells should be arranged in sequence as given below, beginning at either end of the battery:

(a) Cells containing all old plates.

(b) Cells containing all old negatives and all new positives.

(c) Cells containing all new negatives and all old positives.

(d) Cells containing all new plates.

In this case charged negatives are preferable but not essential.

New positives and charged negatives which have not been allowed to dry require a relatively short initial charge (about 10 hours), which may be given to the battery as a whole, but to assume a predetermined amount of charge is dangerous and the charge must not be considered complete until the specific gravity and voltage, with the current at or near normal, have reached a two-hour maximum.

If dry negatives are used the long charge required for a new battery will be necessary (see "Initial Charge" page 6). If such negatives are installed in only part of the cells, such cells should preferably be separately charged (see "Special Charging" page 22).

JARS AND TANKS. General. Care should be taken to prevent the lead flaps on lead lined wood tanks from becoming bent in so that they touch the wood-work, in order that the electrolyte, if any collects on the flaps, may fall clear of the tanks. Tanks as received from the manufacturer have wood packing strips under the lead flaps to protect them from being bent out of shape. These should be removed before putting the battery into service.

Electrolysis of Tank Linings. Care must also be taken to prevent the tank flaps of adjacent cells from coming in contact as this will cause electrolysis of the tank linings. The linings may also be damaged if the elements come in contact with them.

Tanks must be kept dry and clean in order to prevent leakage to ground, as a very small leakage of current from the cells to ground may in time corrode the tank linings by

electrolytic action. With tank batteries mounted on other than oil insulators particular care must be taken to keep the insulators free from dirt and acid-laden moisture (see "Cleanliness" page 36). Oil insulators require only infrequent cleaning.

Repairs to Jars or Tanks. If for any reason a jar or a tank has to be removed, the plates should be taken out, and the negatives immediately placed in a non-metallic vessel, (one of lead excepted), containing clean water, or in the free space of adjacent cells; the positives may be allowed to dry. The wood separators should first be removed and stored in the free space of adjacent cells; this should be carefully done to avoid breakage. Broken or damaged separators should be discarded and new ones provided in their place. Care should be taken that neither the negative plates nor the wood separators be allowed to dry out (see "Treatment Of Dry Plates," page 25).

While the cell is out of circuit, the remaining cells should be charged at a rate which will maintain the bus voltage at or above the minimum required to operate the office.

Upon completion of repairs, the plates and wood separators should be replaced and immediately covered with electrolyte. The cell should not be connected into circuit during discharge of the battery, but preferably just before starting a charge, in order that the plates may receive the benefit of the ensuing charge. If the cell readings indicate that it is then not fully charged it should be given special treatment (see "Cells In Trouble" page 21). If, on account of a broken jar, the plates have become dry, the cell will require a prolonged charge (see "Treatment Of Dry Plates" page 25).

In order to avoid delay in case a glass jar becomes broken it is recommended that a spare jar be always kept on hand at the central office.

PROTECTIVE COATING (Paint, etc.). To properly preserve the battery woodwork, particularly the boxes of lead-lined tanks, and also the metal work, care must be taken to keep these parts well protected.

The woodwork being thoroughly painted at the start, oiling it occasionally with boiled linseed oil, applied with a cloth rather than a brush, is recommended; repainting will then be necessary less frequently. A satisfactory paint is one with a heavy asphaltum base.

For metal work which is not lead or lead coated the above paint may also be used. Exposed copper connections may be further protected by coating with vaseline. If corrosion starts, thoroughly clean and repaint at once. In cleansing remove the corroded material by scraping and then washing with bicarbonate of soda solution. **Do not at any time allow either the products of corrosion or the washing solution to fall into the cells.**

SEDIMENT. **General.** The accumulation of sediment in the bottom of the cells must be watched and removed when the clearance under the plates has been reduced to 1/2 inch. However, due to the circulation of the electrolyte when the cell gasses on charge the sediment is usually deepest under the middle plates, and if it is levelled over the bottom of the cell its removal can be deferred for some time. The levelling can be done by using an L-shaped device made of wood or of metal not appreciably acted upon by the electrolyte, such as aluminum; a heavy copper wire protected by rubber tubing can be used. Under no circumstances must the sediment be allowed to reach the plates as, if this occurs they will deteriorate rapidly due to the short circuit thus formed. .

Removal from Glass Jar Batteries. To remove the sediment from glass jar batteries having bolted connections between the cells, the best method, except possibly in the case of the largest size cells of considerable weight, is,

after first fully charging the battery, to lift the elements out of the jars in rotation at the same time closing the battery circuit with a jumper. In handling the elements the separators should be disturbed as little as possible; if any are damaged they should be replaced with new ones. Pour off the clear electrolyte into a spare clean jar or carboy; dump the sediment and wash the jar with water; replace elements in jar and pour in the electrolyte, adding enough new of 1.210 specific gravity to cover the plates. The gravity should be adjusted to normal as outlined under "Addition Of Acid" page 5. For instructions regarding the replacement of bolted connections see page 22. The elements must not be exposed to the air except for the very shortest possible time, and must not be allowed to dry out (see "Treatment Of Dry Plates" page 25); for this reason only one cell at a time should be emptied, cleaned and refilled. While one cell is being cleaned the remaining cells should be charged at a rate which will maintain the bus voltage at or above the minimum required to operate the office.

A modification of the above method, where a spare battery and sufficient storage capacity for the electrolyte from a number of cells are available is to first take down several cells, pouring the electrolyte into a container, and use all new electrolyte of 1.210 specific gravity for these cells. The removed electrolyte is then to be adjusted to 1.210 specific gravity by adding 1.400 specific gravity acid; this is then used for the second lot of cells taken down and so on through the rest of the battery. This method insures the automatic adjustment of gravity as the work progresses and the proper gravity is secured with minimum labor.

Removal from Tank Batteries. If the cell connections are burned together as in tank batteries, the sediment can be taken out by using a special form of scoop for drawing it from beneath the plates and then removing it from the jar or tank. The scoop used should be made of hard wood (preferably boiled in paraffine) or of aluminum and may be obtained from the manufacturer. In cells having a large number of plates the scoop will not reach the sediment in

the middle of the cell and it is therefore necessary to take out several of the middle plates in order to remove this sediment. A thin board the width of the plates should be inserted in the open space thus made and used as a backing against which to hold the sediment in the scoop. After the sediment is removed the specific gravity of the electrolyte must be adjusted to normal (see "Addition Of Acid" page 5).

Reburning Plates in Tank Batteries. In cases where the removal of sediment by the scoop method necessitates cutting out a few plates from the cells the lugs should be cut in a V-shape so that when they are replaced they can be burned from the bottom of the cut and the V filled up. The plates can be readily reburned into place by means of a hydrogen flame or by a hot carbon rod, some of the cells of the battery being used as a source of current for heating the carbon. The latter method will usually be the more convenient where only a few plates are to be burned. If a large number of plates are to be burned the hydrogen flame is recommended.

The arc burning outfit consists of a carbon holder with cable, clamps and 1/4 inch carbon rods. A burning tong or mould is placed on the lug to prevent any molten lead from escaping.

From three (3) to six (6) cells are required for this work and the number chosen in any case should be sufficient to heat the carbon to a bright cherry red while it is in contact with the joint. A little experience will soon enable one to determine when a satisfactory degree of heat is obtained.

The cable is connected by means of the clamp to a cell in the battery the required number of cells away from the joint to be burned, and either positive or negative to it. Care should be taken that good contact is made by the clamp, the lead being scraped thoroughly clean before the connection is made. The carbon should be sharpened to a long point like a lead pencil and should project not more than three (3) inches from the holder. The latter should be cooled off occasionally by plunging it, carbon and all,

into a pail of water. After being used for a short time it will be found that the carbon will not heat properly, due to a film of scale formed on the surface. This should be cleaned off with a knife or file, as occasion requires.

Additional lead to make a flush joint should not be added until the metal of the pieces to be joined has melted. The carbon should be moved around to insure a solid joint at all points.

Blue or smoked glasses must be worn during the burning operation.

Charging Battery after Removal of Sediment. After the sediment has been removed from all the cells the battery should be given an overcharge, continuing until a five-hour gravity maximum is reached. At the end of the charge the specific gravity of the electrolyte should again be adjusted, if necessary, to normal.

ACCESSORIES.

CELL COVERS. To reduce the diffusion of acid spray, the amount of evaporation, and the danger of foreign matter falling into the electrolyte, a glass cover should be laid across the top of each cell. Covers for two-plate type cells are moulded with lips to prevent them from being accidentally displaced. For larger cells the covers are made of sheet glass and leave sufficient room to permit the addition of water and the taking of hydrometer and thermometer readings without removing the cover. In certain cases of glass jar batteries, creeping of the electrolyte along the glass covers to the outside of the jars may occur. This is usually due to the cells not being level and can be overcome by allowing one edge of the cover to rest inside the jar on the top of the plates. Covers should be kept clean by occasionally removing them from the cells and washing.

HYDROMETER. The hydrometer used should preferably be of the plain type and of the proper size for the cells in which it is to be used, (see table below). Signalling hydrometers may be useful in some cases but are not recommended for general use.

Hydrometer Type	Used with Cells, Type
B	BT, CT, B, C
E	PT, ET, D, E
H	F and larger

THERMOMETER. A mercury thermometer designed to float in the electrolyte should be used. The calibration scale recommended is marked with degrees Fahrenheit on one side and with temperature-gravity corrections on the other.

AUTOMATIC CELL FILLER. An automatic cell filler on the pilot cell which will keep the electrolyte in this cell at the proper height is recommended for use with all batteries of type E cells and larger.

GENERAL.

THE BATTERY ROOM. **Ventilation.** The battery room or casing must be properly ventilated by means of one or more suitable vents, in order that the gasses given off from the battery during charge may be promptly removed, the air kept dry and the temperature moderate. **Do not bring an exposed flame into the battery room or casing** while the battery is being charged or before the room or casing has been entirely freed of gas. It is always desirable to have one or more windows in the battery room.

If the room temperature is very high—that is, considerably over 80° F.—for any great length of time, the life

of the plates may be somewhat shortened. If the temperature is low, no injury to the battery will result, but the available capacity is reduced during the period of low temperature.

It is important that the circulation of air should be sufficient to keep the racks, insulators, and cells free from dampness which might cause grounding of the battery itself or its connecting circuits.

Light. The provision for illumination should be such that all parts of the battery can be readily inspected at any time, day or night. An outlet (protected against attack by acid fumes) should be provided to which a lamp on an extension cord can be connected.

Protective Coating (Paint, etc.). The walls and ceiling of the battery room should be painted with a white lead or combination white lead and zinc white paint, preferably tinted a light yellow or cream color, as these colors readily diffuse the light and are not very susceptible to acid stains. If the door or window casings are of metal particular care should be taken to keep them well protected.

The floor of the battery room or casing should be painted with a black asphaltum paint slightly thinned with turpentine to accelerate the drying. At least four coats are usually required.

Cleanliness. Cleanliness in the battery room is essential. The floor should be washed frequently and the tanks, trays, racks, insulators and all metal work should be frequently wiped off. If there is any metal work over the battery this should be given particular attention. At longer intervals (at least once a year) the floor should be washed with a saturated solution of bicarbonate of soda (ordinary cooking soda) and all the apparatus in the room should be wiped off with a cloth moistened with the same solution in order to neutralize any accumulation of acid spray from the electrolyte. Acid is present as long as the soda effervesces. Rinsing with water should follow the application of the

soda solution and the room should be thoroughly ventilated to insure complete drying. The soda solution should not be allowed to get into the cells.

RECORDS. **General.** For conveniently recording the daily and weekly readings, the accompanying "Storage Battery Weekly Report" form is suggested.

Curves of Specific Gravity Readings. It is also suggested that curves be plotted showing the specific gravity of each cell at the end of each overcharge. These curves will indicate changes in the condition of each cell over a considerable length of time and will show at a glance whether or not the battery has been receiving proper attention. The attached form, "Overcharge Specific Gravity Readings On Individual Cells" is suggested for this purpose.

TESTING.

GENERAL. At such intervals as may be thought necessary to determine whether the cells meet the requirements of the Specifications under which they are furnished the following tests may be made.

CAPACITY. The test for capacity should be made after the battery has received an overcharge and it has been determined that every cell is fully charged.

The capacity test at the 8-hour rate may conveniently be made in service by using a water rheostat to supplement the switchboard and battery machine loads. Instead of using a water rheostat, the charging generator can be used as a motor to supplement the switchboard load as follows: After disconnecting one terminal of the shunt reversing coil of the circuit breaker and connecting the charging set to the battery in the usual manner, the generator rheostat may be adjusted to permit the battery to drive the generator, care being taken not to exceed the rated current

output of the generator. When the current taken by the generator is more than enough for the combined no-load losses, power will be delivered by the motor to the line. Where sufficient motor generator capacity is not available a gas engine generator set may be used, the engine furnishing a brake, adjustable within certain limits if necessary, by varying the compression at the relief valve.

With the usual arrangement where the power board ammeter is provided with a zero center scale and a shunt in the common charge and discharge lead, the total battery discharge current can be read direct. Where no common shunt is available the generator ammeter leads should be reversed.

This test should be made under the direction of an engineer and care should be taken not to seriously overspeed a gas engine set, or a motor generator set in the event that the motor should be accidentally disconnected from the line.

The capacity test should be timed so that complete discharge will be reached shortly after midnight, or at some other time when the office load is light. The battery should be immediately charged so that the office will not be without battery reserve longer than is necessary.

It is not generally practicable in telephone service to discharge the battery sufficiently to obtain its full capacity, i.e., until the battery voltage reaches an average of 1.75 volts per cell. On this account the test should be considered complete when, while discharging at the 8-hour rate, the voltage of any individual cell falls to 1.75 volts, provided this does not bring the total battery voltage below an average of 1.82 volts per cell, which is the minimum required to operate the office. The capacity obtained by stopping the test at this voltage limit is approximately 94 per cent. (93% to 95%) of the full capacity of the battery. Under normal operating conditions the average discharge rate is appreciably less than the 8-hour rate and the capacity obtainable from the battery under these conditions is somewhat greater than is obtainable at the 8-hour rate.

The readings recommended for the test, beginning when the discharge is started, are as follows: Current, battery voltage, pilot cell voltage, specific gravity and temperature at least once each half hour; individual cell voltage, specific gravity and temperature at least once each hour. A complete set of readings should also be taken at completion of the discharge. All voltage readings must be taken with current flowing, but the final gravity and temperature readings may be taken immediately after the discharge is stopped. The temperature of the battery room should be recorded at the beginning and end of the test.

After the battery voltage has fallen to an average of about 1.90 volts per cell, individual cell voltage readings should be taken at frequent intervals (not exceeding 15 minutes apart) in order to locate any cells which may be appreciably below the average at the end of the discharge.

The test for full rated capacity may be made any time between 1½ and 2½ years after installation for batteries receiving one (1) overcharge a week, or any time between two (2) and three (3) years for batteries receiving one (1) overcharge every two (2) weeks.

CADMIUM TEST. The cadmium test is a refinement in storage battery testing that is apt to be misleading unless handled by experienced men, and therefore, its general use is not recommended. When properly carried out, however, the cadmium test is of value, in cases where low capacity is experienced, in determining whether the positive or negative plates are the cause.

In using the cadmium to determine the condition of the plates, local conditions, such as temperature, rate of discharge, etc., have to be taken into consideration as well as the results given by the cadmium, and not until considerable experience has been had in using the cadmium should much dependence be placed on the readings.

In any case, if it is thought desirable to make use of the cadmium test, complete instructions for doing so should be obtained from the manufacturer of the batteries.

VOLTAGE. The overcharge voltage should be measured while the normal charging current is flowing, after the voltage and gravity have ceased to rise.

The discharge voltage should be measured during a capacity test, as outlined above.

AMPERE HOUR EFFICIENCY. The ampere hour efficiency test may conveniently be made when the capacity test is carried out. Just before stopping the overcharge which immediately precedes the capacity test discharge the specific gravity of the pilot cell should be very accurately read. The capacity test discharge should then be made, and on the following charge the number of ampere hours required at normal rate to raise the pilot cell gravity to the value attained on the preceding charge should be noted, allowance being made for any difference in cell temperature on the two charges. The ratio of the ampere hours obtained on the discharge to the ampere hours required on the charge will be the ampere hour efficiency of the battery.

RESISTANCE. On account of the relatively small electrical inductance and capacity of the conventional lead plate sulphuric acid type battery, the internal impedance can generally be determined with sufficient accuracy by measuring the "virtual internal resistance." This may be done by noting the instantaneous change in battery terminal voltage for sudden changes in charge and discharge currents, the value for resistance being the quotient obtained by dividing the voltage change by the current change. Rapid changes and readings are necessary to minimize the effects of polarization, which would not be present with measurements made by alternating current. The average value obtained from several sets of readings should be taken.

Unless it is suspected that a battery is abnormal, resistance tests ordinarily need not be made.

SUMMARY OF IMPORTANT POINTS.

1. Give the battery the proper amount of charge but avoid excessive charging. See page 9
2. Give a "regular charge" daily or every other day and an "overcharge" weekly or every two weeks as required. See page 10
3. Start "regular charge" when sp. gr. of pilot cell has fallen the proper number of points below the value attained at end of preceding overcharge. See page 14
4. Stop "regular charge" when sp. gr. of pilot cell reaches a value 5 points below the value attained at end of preceding overcharge. See page 14
5. When giving an "overcharge," continue charging until the sp. gr. and voltage show no change in 5 successive readings taken at 15-minute intervals. (Proportionately longer if charging rate is less than normal). See page 15
6. Whenever possible use the specific gravity method for following the state of charge. See page 11
7. Correct all hydrometer readings to 70° F. See page 5
8. Battery and cell readings must be regularly taken and recorded on the forms provided for this purpose. See page 19
9. Unless the pilot cell is equipped with an automatic cell filler add water to this cell at least once a day to keep electrolyte at the fixed level. See page 10
10. Use only pure water for replacing evaporation. See page 6
11. Do not allow top of plates in any cell to become exposed. See page 6
12. Contamination of the electrolyte by foreign matter must be avoided. See page 4
13. Inspect each cell at regular intervals. See page 20
14. Keep battery room well ventilated at all times. See page 35
15. Do not bring an exposed flame into the battery room. See page 35

A. T. & T. Co. Form E-118
Replacing Form 1158

STORAGE BATTERY INITIAL CHARGE REPORT.

SHEET No.....

.....Company.

.....Exchange. Battery No..... .....Cells. Type..... Equipment.....Plates per Cell.
Capacity.....Plates per Cell.

Charge Started.....A.M./P.M.....191....., Completed.....A.M./P.M.....191.....

Date	Time	Amperes	Ampere Hours.	No. of Cells in Circuit	Total Volts for Cells in Circuit.	Average Volts per Cell in Circuit.	Pilot Cell [Cell No.....] Hyorom. Reading [Observed Sp. Gr.]	Temperature Electrolyte	Specific Gravity [Cor'ct'd to 70° F.]	Volts	Temp. Air-Every 8 hrs.

A. T. & T. CO. FORM E-127

STORAGE BATTERY WEEKLY REPORT

.....COMPANY.....EXCHANGE DATE. FROM .....TO .....191.....(INCL.)

BATTERY No..... .....CELLS TYPE..... EQUIPMENT.....PLATES PER CELL CAPACITY.....PLATES PER CELL

WATER WAS ADDED TO REPLACE EVAPORATION .....(DATE) IS PILOT CELL EQUIPPED WITH AUTOMATIC FILLER.....

CELLS NOT GASSING PROPERLY ON OVERCHARGE, Nos.....

CELLS GIVEN SPECIAL ATTENTION DURING WEEK (STATE ATTENTION GIVEN UNDER "REMARKS") Nos.....

DAILY READINGS

	BEFORE CHARGE						START	END OF CHARGE					
	PILOT CELL (Cell No. .....)				BATTERY		BATTERY	PILOT CELL				BATTERY	
DAY	TIME	HYDROM. READING (OBSERVED SP. GR.)	TEMPERATURE ELECTROLYTE	SPECIFIC GRAVITY (CORRECTED TO 70° F.)	VOLTS	AMPERES	CHARGING AMPERES	TIME	HYDROM. READING (OBSERVED SP. GR.)	TEMPERATURE ELECTROLYTE	SPECIFIC GRAVITY (CORRECTED TO 70° F.)	VOLTS	AMPERES

WEEKLY READINGS

	INDIVIDUAL CELL READINGS						PILOT CELL AND BATTERY READINGS (END OF OVERCHARGE—15 MINUTE INTERVALS)					
	BEFORE OVERCHARGE Readings taken A.M. P.M.			AFTER OVERCHARGE Within 15 minutes after stopping overcharge			PILOT CELL Max. Sp. Gr. on preceding overcharge.....				BATTERY	
CELL	HYDROM. READING (OBSERVED SP. GR.)	TEMPERATURE ELECTROLYTE	SPECIFIC GRAVITY (CORRECTED TO 70° F.)	HYDROM. READING (OBSERVED SP. GR.)	TEMPERATURE ELECTROLYTE	SPECIFIC GRAVITY (CORRECTED TO 70° F.)	TIME	HYDROM. READING (OBSERVED SP. GR.)	TEMPERATURE ELECTROLYTE	SPECIFIC GRAVITY (CORRECTED TO 70° F.)	VOLTS	AMPERES
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

SAMPLE FORM
STOCK FORMS 8½" X 11"

REMARKS

(THESE TO COVER ANYTHING UNUSUAL IN CONNECTION WITH THE OPERATION OF THE BATTERY.)

READINGS TAKEN BY.....

APPROVED BY .....

DIRECTIONS

DAILY READINGS.

Daily readings should begin on the day of overcharge.

"Before Charge" readings to be taken just before charge is started.

"Battery Charging Amperes" to be recorded as soon as charge is started.

"End of Charge" readings to be taken just before charge is stopped.

In case the battery is not charged daily, write in "No. Chg." across the space for the "End of Charge" readings for that day, but record the specific gravity and temperature of the pilot cell on such day at the usual time of starting the charge.

If practicable both pilot cell readings and those called for under "Battery" should be taken. The voltage readings are on the battery as a whole, not on individual cells.

WEEKLY READINGS.

Individual cell specific gravity readings to be taken once a week, before starting the overcharge if the battery is overcharged weekly, and also on the corresponding day of the off week if not overcharged weekly. Readings to be taken at the same hour each time.

Individual cell specific gravity readings to be taken within 15 minutes after stopping the overcharge.

Pilot cell and battery readings at end of overcharge are to be taken at 15-minute intervals after pilot cell specific gravity reaches a value from 2 to 5 points below the maximum reached on the preceding overcharge.

A.T.&T.CO. FORM E-128

OVERCHARGE SPECIFIC GRAVITY READINGS ON INDIVIDUAL CELLS

_____ Company _____ Exchange

Battery No. _____ _____ Cells. Type _____ Equipment _____ Plates per Cell. Capacity _____ Plates per Cell.

IF PLATE EQUIPMENT IS CHANGED, NOTE NUMBER OF PLATES ADDED AND DATE UNDER "REMARKS"

Cell No. [Designate Pilot Cell]	Spec. Grav. [Corrected to 70° F.]	Date [1 Div. = 1 Week]	REMARKS
	1,210		
	1,200		
1			
	1,190		
	1,180 1,210		
	1,200		
2			
	1,190		
	1,210 1,180		
	1,200		
3			
	1,190		
	1,180 1,210		
	1,200		
4			
	1,190		
	1,210 1,180		
	1,200		
5			
	1,190		
	1,180 1,210		
	1,200		
6			
	1,190		
	1,210 1,180		
	1,200		
7			
	1,190		
	1,180 1,210		
	1,200		
8			
	1,190		
	1,210 1,180		
	1,200		
9			
	1,190		
	1,180 1,210		
	1,200		
10			
	1,190		
	1,210 1,180		
	1,200		
11			
	1,190		
	1,180		

SAMPLE FORM
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